

DETERMINATION OF CADMIUM (Cd) AND CHROMIUM (Cr)  
CONCENTRATION AT SURFACE AND SUB SURAFCE SOIL AROUND  
NEWLY-CLOSED LANDFILL IN ULU TUALANG, TEMERLOH

JASHIRATULAIN BT AHMAD JAILANI

A report submitted in partial fulfillment of the  
requirement for the award of the degree of  
Bachelor of Chemical Engineering

Faculty of Chemical Engineering  
Universiti Malaysia Pahang

DECEMBER 2010

## ABSTRACT

Heavy metal contamination in landfill is one of the major concerns in order to avoid harmful effects towards health living and environment. The aim of this study is to come out with the distribution of the concentration of Cadmium (Cd) and Chromium (Cr) contaminated in soil of closed landfill, to compare it with the United States Environmental Protection Agency (USEPA) soil standard. The 200 grams (g) of 25 soil samples were taken at 25 points from a newly closed landfill in Ulu Tualang, Temerloh at two (2) parts of soil partition which are in surface (0-2 inch) and subsoil (2-10 inch), respectively. The sample was processed using acid digestion method of SCL (Southern California Laboratory) and was analyzed using Flame Atomic Absorption Spectrometry (FLAA). The range of Cd concentration that had been analyzed is from 49.4 to 66.15 mg/kg, while for Cr concentration determination, the result showed that the range is between 5.35 to 71 mg/kg. Available results from the landfill indicated that all concentration of Cd is exceeded the USEPA soil standard while the data for Cr is under the control value. The result can be used in future for reference and if possible, it may be needed for soil treatment if there are any future plans or activities for the landfill.

## ABSTRAK

Pencemaran logam berat di sekitar tapak pelupusan sampah adalah salah satu masalah yang harus di ambil berat untul mengelakkan kesan yang merbahaya terhadap kesihatan hidupan dan alam sekitar. Objektif kajian ini adalah untuk mendapatkan taburan kepekatan Kadmium (Cd) dan Kromium (Cr) yang tercemar di dalam tanah pada tapak pelupusan sampah, untuk membandingkannya dengan nilai United States Protection Agency (USEPA) Soil Standard. 25 sampel tanah yang mempunyai berat 200 gram (g) setiap satu di ambil dari 25 titik kajian di tapak pelupusan sampah yang baru ditutup di Ulu Tualang, Temerloh pada dua bahagian tanah iaitu pada permukaan (0-2 inci) dan sub permukaan (2-10 inci) tanah. Sampel-sampel itu telah diproses berdasarkan kaedah penghadaman asid dan dianalisis menggunakan Flame Atomic Absorption Spectrometry (FLAA). Kepekatan kadmium di dalam tanah adalah di antara 49.4 hingga 66.15 mg/kg, manakala kepekatan kromium pula adalah di antara 5.35 hingga 71 mg/kg. Data dari kajian menunjukkan semua nilai kepekatan kromium bagi sampel yang dikaji adalah melebihi USEPA Soil Standard, manakala bagi kromium pula semua data adalah masih di bawah nilai kawalan. Data dari kajian boleh digunakan sebagai panduan untuk masa hadapan dan jika berkemungkinan ianya boleh diperlukan bagi rawatan tanah jika terdapat rancangan atau sebarang aktiviti yang ingin dijalankan di tapak pelupusan sampah berkenaan.

## TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENTS	iv
	ABSTRACT	v
	ABSTRAK	vi
	TABLE OF CONTENTS	vii
	LIST OF TABLES	ix
	LIST OF FIGURES	x
	LIST OF ABBREVIATIONS	xi
	LIST OF SYMBOLS	xii
	LIST OF APPENDICES	xiii
<b>1</b>	<b>INTRODUCTION</b>	
	1.1 Research Background	1
	1.2 Problem Statement	2
	1.3 Objective of Study	3
	1.4 Scope of Research	3
	1.5 Rationale and Significance of Study	6
<b>2</b>	<b>LITERATURE REVIEW</b>	
	2.1 Municipal Solid Waste (MSW)	8
	2.2 Type of Municipal Solid Waste (MSW)	
	2.2.1 Nonhazardous MSW	10

2.2.2	Hazardous MSW	10
2.3	Solid Waste Management (SWM)	11
2.4	Heavy Metal	12
2.5	Cadmium (Cd)	
2.5.1	Background of Cd	13
2.5.2	Health Effects of Cd	14
2.5.3	Environmental effects of Cd	14
2.6	Chromium (Cr)	
2.6.1	Background of Cr	16
2.6.2	Health Effects of Cr	17
2.6.3	Environmental effects of Cr	18
2.7	Landfill	19
<b>3</b>	<b>METHODOLOGY</b>	
3.1	Apparatus	21
3.2	Reagent	22
3.3	Procedure	23
3.3.1	Collection of Soil Samples	24
3.3.2	Preparation of Samples	24
3.3.3	FLAA Analysis	25
3.4	Preparation of Standard Calibration Curve	27
<b>4</b>	<b>RESULT &amp; DISCUSSION</b>	
4.1	Introduction	28
4.2	Sample Spiking	29
4.3	Data Assessment	29
<b>5</b>	<b>CONCLUSION &amp; RECOMMENDATION</b>	
5.1	Conclusion	36
5.2	Recommendation	37
	<b>REFERENCES</b>	38
	Appendices A-B	40

**LIST OF TABLES**

<b>TABLE NO.</b>	<b>TITLE</b>	<b>PAGE</b>
2.1	Comparison of leachate quality of Kuwait with other leachates reported for developed countries	9
4.1	pH of soil samples	30
4.2	Physical properties of soil samples	30
4.3	Concentration of Cd and Cr at surface and subsurface soil	34

## LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
1.1	Map location of closed landfill in Ulu Tualang	5
1.2	Partitions of soil	6
3.1	Grid of sampling points	24
3.2	Schematic diagram of research methodology	26
4.1	Grid of chosen sampling points for spike samples	28
4.2	Distribution of Cd concentration at surface soil	31
4.3	Distribution of Cd concentration at sub surface soil	31
4.4	Distribution of Cr concentration at surface soil	32
4.5	Distribution of Cd concentration at sub surface soil	32
4.6	Distribution of Cd at surface and sub surface soil	33
4.7	Distribution of Cr at surface and sub surface soil	34

## LIST OF ABBREVIATIONS

BOD	-	Biological Oxygen Demand
Cd	-	Cadmium
COD	-	Chemical Oxygen Demand
Cr	-	Chromium
FLAA	-	Flame Atomic Absorption Spectrometry
GFAA	-	Graphite Furnace Atomic Absorption Spectrometry
ICP-AES	-	Inductively Coupled Plasma Mass Spectrometry
ICP-MS	-	Inductively Coupled Plasma Atomic Emission Spectrometry
MSW	-	Municipal Solid Waste
Ni-Cd	-	Nickel-Cadmium
NTP	-	National Toxicology Program
SWM	-	Solid Waste Management
USEPA	-	United States of Environmental Protection Agency



**LIST OF SYMBOLS**

%	-	percentage
$\pm$	-	plus minus
$^{\circ}\text{C}$	-	degree celcius
cm	-	centimeter
g	-	gram
kg	-	kilogram
m	-	meter
mg/kg	-	milligram per kilogram
mg/L	-	milligram per liter
mL	-	mililiter
mm	-	milimeter
ppm	-	part per million

**LIST OF APPENDICES**

<b>APPENDIX</b>	<b>TITLE</b>	<b>PAGE</b>
A	USEPA Soil Standard	40
B	Experimental Work Images	41

## **CHAPTER 1**

### **INTRODUCTION**

#### **1.1 Research Background**

An experimental method of research was performed to assess the presence or absence of heavy metals in newly closed landfill in Ulu Tualang; and the concentration of each heavy metal when present. With the location of the landfill that is located around an industrial and residential area, the chance of contamination of heavy metal is high there.

After a long time, waste that decomposed at the landfill will make the soil become polluted and may contain large amount of heavy metal. There are some of heavy metal can react with rain rich oxygen to form sulphur and then produces macromolecule of sulphides (P.J. *et al.*, 2006). These hazardous molecules will influences the quality of atmosphere thus may affect health and life of animal and human being that closed to the landfill. Usually after the landfill is closed, that placed is usually reconstructed as recreational places or residential area. A lot of problems will occur if the soil becomes porous and not stable because of the presence of heavy metal in the soil. Even though there are some heavy metal that may good for the soil, but most of heavy metal that come from industrial waste are toxic and dangerous to human. This issues then will make the reconstructed area are not safe and not suitable for human lives. (G.M. Greenway & Q. J. Song, 2002)

## 1.2 Problem Statement

Modern life today is unexceptional from contacting with heavy metals directly or non directly. Most common example for heavy metals enter human body is via food, drinking water and air. If it is not due to the daily requirements, it may also occur unnoticeable which if exist in high concentration, may lead to poisonous. Simply define, heavy metals are metal and metal compounds that may harm human health when absorbed or inhaled. Undeniable, heavy metals do needs in life but just in a small amount, it becomes toxic when have it in an exceed amount. Heavy metals cannot be degraded or destroyed, and what make it worse is that they tend to bioaccumulate which means the concentration of heavy metals may increase in biological organism over time.

Heavy metals are example of wastes that are not allowed to dispose off to landfill due to its potential hazardous impact on public health and the surrounding environmental. Heavy metals that appears in disposal site comes from variety of sources such as batteries, consumer electronics, ceramics, light bulbs, house dust and many more. This type of waste has to dispose off at a place especially designated for such purposes. It is impossible to ensure that all the disposal waste received by disposal landfill are hundred percent free from heavy metals and as the landfill is located in an open area, heavy metals may exist there naturally whereby acidic rain will be one of the source.

Main purpose of this research is to ensure the existence of Cadmium (Cd) and Chromium (Cr) for surface soil and subsoil in 25 points of drilling at closed landfill located in Kampung Ulu Tualang, Mukim, Temerloh, Pahang. Used to be the second largest landfill in Pahang, it received hundred tones of waste per day whereby heavy metals are also included as the component of waste. The soil sample is taken somewhere around this landfill with gridding measurements of 50m X 50m. 25 soil samples are taken in every points of 10m X 10m for surface soil and subsoil. Advance for the main

purpose is to determine either Cd or Cr is the higher concentration in surface soil and subsoil for each drilling.

### **1.3 Objective of Study**

- i. To ensure the existence of Cd and Cr in surface soil and subsoil follow by the determination of the concentration of each of the heavy metals.
- ii. To make a comparison of the value of the concentration of Cd and Cr with USEPA soil standard.
- iii. To develop a distribution model of the concentration of Cd and Cr at each point as well as at the part of soil (surface and subsurface soil).

### **1.4 Scope of Research**

#### **1.4.1 Methodology**

For this purpose, collection, preparation and analysis of sample was done in determining the heavy metal concentration. The concern part of determining the result is the preparation of the samples where an acid digestion method was involved. The purpose of this method is to solubilize all the elements of interest. To do this, a digestion procedure must perform two distinct tasks; (D. E. Kimbrough & J. Wakakuwa, 1992).

1. It must decompose the sample matrix to expose the entire mass to the acid cocktail.
2. It must react with the elements of interest to form water soluble compounds.

To complete the process, dilution medium is added to form a solution that is suitable for analysis by a variety of analytical instruments (typically Flame Atomic Absorption Spectrometry (FLAA), Inductively Coupled Plasma Mass Spectrometry (ICP-AES), Inductively Coupled Plasma Mass Spectrometry (ICP-MS), Graphite Furnace Atomic Absorption Spectrometry (GFAA). Dilution medium that may be used are like distilled water, deionized water and ultra pure water.

#### **1.4.2 Area description**

A landfill, also known as a dump or rubbish dump is a site for the disposal of waste materials by burial and is the oldest form of waste treatment. Historically, landfills have been the most common methods of organized waste disposal and remain so in many places around the world.

Ulu Tualang closed land fill located in Temerloh Pahang with an area of approximately 20 acres, used to be the second largest landfill in Pahang, it had operated many years before it had been closed recently. It had no longer available to accommodate the waste and need to use landfill in Bera for the purpose. Located around an industrial area and residential area which was the major sources of waste in the disposal landfill of Ulu Tualang. 60% of waste in the landfill was distributed by the factories from the nearby industrial area. The remaining is from the residential area waste. The list below are some of the factories that are operate around Ulu Tualang landfill :

- i. Megaply Industries (M) Sdn Bhd (Piling)
- ii. Intan Suria Sdn Bhd (Frame-picture wood products)
- iii. SQ Wooden Picture Frame Moulding Sdn Bhd (Picture frame-wholesaler & manufacture)

- iv. LCS Precast Sdn Bhd (Piling)
- v. Mentakab Stainless Steel Works (Stainless Steel Fabricators)
- vi. Syarikat Perniagaan Boon Wee (Biscuits-Wholesaler & manufacturer, food products)
- vii. Mentakab Agricultural Machinery Sdn Bhd (Agricultural equipment & supplies, tractor distributors & manufacturers)

What can be concluded is that most of the factories around the closed landfill are operating with wood and steel base product.



Figure 1.1: Map location of closed landfill in Ulu Tualang

The soil sample examined was taken from Ulu Tualang newly closed landfill. Generally, parts of soil are divided to 4 partitions. Each represents as 0 A, B, C where the partition is categorized according to their depth as in Figure 1.2.

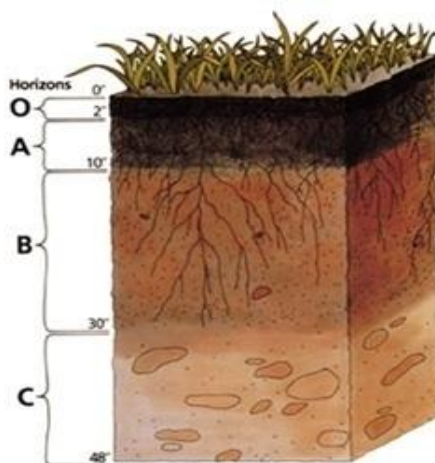


Figure 1.2: Partitions of soil

O : 0-2 inch = 0 – 5.08 cm

A : 2-10 inch = 5.08 – 25.4 cm

B : 10-30 inch = 25.4 – 76.2 cm

C : 30-40 inch = 76.2 – 121.92 cm

For this research, part A and B only that was covered throughout the experiment where A and B represent surface and sub surface soil partitions. Gridding was done at the closed landfill with measurement of 100mX100m, where 25 points will be measured in the grid with measurement of 10mX10m. The location of gridding was chosen as advised by the representative of the Temerloh Municipal Council. At each point, 2 samples of 200 g were taken as part of surface soil and subsoil.

## 1.5 Rationale & Significance of Study

This study was done on the significance of the closed landfill in Malaysia. In the future, mostly the closed landfill will be developed to something that provides benefit to



human. Currently, there is a residential area had been developed from the closed landfill and surely this development need details study also soil remediation to avoid unnecessary incident coming later. Apart from this significance, the closed landfill may give a bad effect towards human health and environment if it is not properly closed. Now, local authorities simply wash their hands off dumps once these are no longer useable since there is no legal document spelling out their responsibilities to ensure closed landfills do not pollute. (*www.thestar.com.my*, 2010). So, the data presented on this study might be needed for future soil remediation.

This study is to determine the existence and the concentration of Cd and Cr in surface soil and subsoil for closed landfill. The result obtained will be compared to the standard United States Environmental Protection Agency (USEPA) Soil Standard. From the comparison, the closed landfill can be predicted as having the potential to do any activity or not. Also, the data might use as a guide for further research of the landfill or for soil treatment as example.

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 Municipal Solid Waste (MSW)**

There has been a significant increase in the generation of municipal solid wastes (MSW) in Malaysia over the last few decades. This is largely a result of rapid population growth in the country. Currently, the generation of municipal solid waste in Malaysia is about 8 million tones per annum. This solid waste volume is still increasing at the rate of 1.5% every year (*Professional Training Program on Integral Solid Waste Management in Southeast Asian Cities*, 2005). The reasons for this trend could be due o the changing of lifestyles, food habits and changes in the standard of living (*Sanitary landfill: Toward Sustainable Development, LUMES 2000-2001*). MSW in cities is collected by the municipalities and transported to designated disposal sites normally at low lying area on the outskirts of the city for disposal. The choice of a disposal site is more a matter of what is available than what is suitable.

A research done by Chai Xiaoli *et al.*, (2007), it shows that more than 90% waste are disposed in landfill at China but this developing country has recently closed more than 1000 landfills because of environmental concern. An example from Chai Xiaoli *et al.*, (2007) research, they stated that after the largest landfill in China, Shanghai Laogang Landfill that constructed in 1985 along the shore of the East China Sea was closed after handling and treats about 30 million tones of refused up to 2005, they preferred MSW

landfill to replaced previous landfill because of its offers potential economic benefits by creates additional disposal capacity for the placement of fresh refuse, and recycles the stabilized, valuable resource.

In a study done by A.F Al-Yaqout *et al.*, (2003), they compared the soil contamination at the leachate landfill from developed country which is USA, Germany and Italy in term of amount of pH, bio-oxygen demand (BOD), chemical oxygen demand (COD) and distribution of heavy metal with their country. The data below shown the result obtained from the study.

Table 2.1: Comparison of leachate quality of Kuwait with other leachates reported for developed countries

<b>Parameter (mg/l)</b>	<b>Kuwait</b>	<b>USA</b>	<b>Italy</b>	<b>Germany</b>
Alkalinity (as CaCO <sub>3</sub> )	250–6340	240– 8965	4250– 8250	-
pH	6.9– 8.2	5.1–6.9	6.0–8.5	5.7– 8.1
BOD	30– 600	13,400	2125– 10,400	400–45,900
COD	157.9–9440	1340– 18,100	7750– 38,520	1630–63,700
Sulfate	55– 3650	0.01– 1280	219–1860	1– 121
Zn	0.0– 4.8	18.8– 67	5 – 7	-
Pb	0– 0.2	0 –4.46	–	–
Cu	0– 0.2	0 –0.1	–	–
Fe	0.3– 54.1	4.2–1185	47–330	8– 79
Ca	5.6– 122	254.1– 2300	0 – 175	70– 290
Mg	5.2– 268	233– 410	827–1469	100–270

## **2.2 Type of Municipal Solid Waste (MSW)**

### **2.2.1 Nonhazardous MSW (A.Y. Abubakar, 2008)**

These are type of wastes if it is discarded does not pose much danger to human health and environment as compared to hazardous municipal solid waste. Some examples of nonhazardous MSW are as follows:

- Packaging waste
- Food and organic waste
- Garden waste
- Plastics
- Bulky waste
- Construction and demolition wastes
- Paper wastes

### **2.2.2 Hazardous MSW (A.Y. Abubakar, 2008)**

Sources of hazardous waste include those from industrial processes, mining extraction, tailings from pesticide based agricultural practices, etc. Industrial operations lead to considerable generation of hazardous waste and in a rapidly industrializing country such as India the contribution to hazardous waste from industries is largest. Hazardous waste generation from industries is also critical due to their large geographical spread in the country, leading to region wide impacts. The annual growth in hazardous waste generation can be directly linked to industrial growth in the country. State such as Malaysia, a developing country which is relatively more industrialized, face problems of toxic and hazardous waste disposal far more acutely than less developed states. The major hazardous waste-generating industries in Malaysia include:

- Petrochemicals
- Pharmaceuticals
- Pesticides
- Paint and dye
- Petroleum
- Fertilizers
- Asbestos
- Inorganic chemicals
- General engineering industries.

During the last 20 years, the industrial sector in Malaysia has increased in size. Hazardous wastes from the industrial sectors also contain heavy metals, cyanides, pesticides, complex aromatic compounds, and other chemicals which are toxic, flammable, reactive, and corrosive or have explosive properties.

### **2.3 Solid Waste Management (SWM)**

In order to have a satisfactory, efficient, and a sustainable system of solid waste management, proper planning, implementation, and management systems must be incorporated in framing the national policy for solid waste management for the country. Present and future ways to manage solid waste stream need consideration of the following aspects. Setting targets for waste reduction. Reduction at source can be accomplished in three ways;

- fees and tax incentives to promote market mechanisms to effect source reduction
- mandatory standards and regulation,
- education and voluntary compliance with policies by business and consumers, (Marcin *et al.*, 1994).

However, these strategies need to be sensitive to the concerns of possible loss of business and jobs in affected industries. Reduction in the quantity of municipal solid waste could affect employment, taxes/revenues, and economic activity in unpredictable ways (Marcin *et al.*, 1994). In particular, there are six elements of solid waste management :

- ✓ Generation
- ✓ Storage
- ✓ Collection
- ✓ Transportation and transfer
- ✓ Processing and treatment
- ✓ Disposal

Among all the technical components, collection, transportation, treatment and disposal of waste need urgent attention.

## **2.4 Heavy metal**

Nowadays, the usage of heavy metals is wide and can be found anywhere. Sooner or later, everything becomes waste including the heavy metals. At the end, all the waste will go to the landfill site for disposal purpose. If the disposal waste is not meet the standard of the heavy metal waste, this may contribute to the heavy metal pollution.

Heavy metal pollution not only affects the production and quality of crops, but also influences the quality of the atmosphere and water bodies, and threatens the health and life of animals and human being (A. Kasassi *et al.*, 2008). In order to avoid any unnecessary incident regarding to heavy metals, guideline of disposing heavy metals needed to practice correctly. The environmental problem with heavy metals is that they

are unaffected during degradation of organic waste and have toxic effects on living organisms when exceeding a certain concentration (S. Esakku *et al.*, 2003).

Heavy metal pollution of the environment, even at low levels, and their resulting long-term cumulative health effects are among the leading health concerns all over the world. For example, bioaccumulation of Pb in human body interferes with the functioning of mitochondria, thereby impairing respiration, and also causes constipation, swelling of the brain, paralysis and eventual death (E. A. Oluyemi *et al.*, 2008).

## **2.5 Cadmium (Cd)**

### **2.5.1 Background of Cd**

Cadmium is a lustrous, silver-white, ductile, very malleable metal. Its surface has a bluish tinge and the metal is soft enough to be cut with a knife, but it tarnishes in air. It is soluble in acids but not in alkalis. It is similar in many respects to zinc but it forms more complex compounds.

About three-fourths of cadmium is used in Nickel-Cadmium (Ni-Cd) batteries, most of the remaining one-fourth is used mainly for pigments, coatings and plating, and as stabilizers for plastics. Cadmium has been used particularly to electroplate steel where a film of cadmium only 0.05 mm thick will provide complete protection against the sea. Cadmium has the ability to absorb neutrons, so it is used as a barrier to control nuclear fission. Cadmium can mainly be found in the earth's crust. It always occurs in combination with zinc. Cadmium also consists in the industries as an inevitable by-product of zinc, lead and copper extraction. After being applied it enters the environment mainly through the ground, because it is found in manures and pesticides.

Naturally a very large amount of cadmium is released into the environment, about 25,000 tons a year. About half of this cadmium is released into rivers through weathering of rocks and some cadmium is released into air through forest fires and volcanoes. The rest of the cadmium is released through human activities, such as manufacturing. Consequently, the main mining areas are those associated with zinc. World production is around 14,000 tonnes per year, the main producing country is Canada, with the United States of America (USA), Australia, Mexico, Japan and Peru also being the major suppliers.

### **2.5.2 Health effects of Cd**

Human uptake of cadmium takes place mainly through food. Foodstuffs that are rich in cadmium can greatly increase the cadmium concentration in human bodies. Examples are liver, mushrooms, shellfish, mussels, cocoa powder and dried seaweed. An exposure to significantly higher cadmium levels occurs when people smoke. Tobacco smoke transports cadmium into the lungs. Blood will transport it through the rest of the body where it can increase effects by potentiating cadmium that is already present from cadmium-rich food.

Other high exposures can occur with people who live near hazardous waste sites or factories that release cadmium into the air and people that work in the metal refinery industry. When people breathe in cadmium it can severely damage the lungs. This may even cause death. Cadmium is first transported to the liver through the blood. There, it is bound to proteins to form complexes that are transported to the kidneys. Cadmium accumulates in kidneys, where it damages filtering mechanisms. This causes the excretion of essential proteins and sugars from the body and further kidney damage. It takes a very long time before cadmium that has accumulated in kidneys is excreted from a human body. Other health effects that can be caused by cadmium are:



- Diarrhoea, stomach pains and severe vomiting
- Bone fracture
- Reproductive failure and possibly even infertility
- Damage to the central nervous system
- Damage to the immune system
- Psychological disorders
- Possibly DNA damage or cancer development

### **2.5.3 Environmental effects of Cadmium (Cd)**

Cadmium waste streams from the industries mainly end up in soils. The causes of these waste streams are for instance zinc production, phosphate ore implication and bio industrial manure. Cadmium waste streams may also enter the air through (household) waste combustion and burning of fossil fuels. Because of regulations only little cadmium now enters the water through disposal of wastewater from households or industries.

Another important source of cadmium emission is the production of artificial phosphate fertilizers. Part of the cadmium ends up in the soil after the fertilizer is applied on farmland and the rest of the cadmium ends up in surface waters when waste from fertilizer productions is dumped by production companies. Cadmium can be transported over great distances when it is absorbed by sludge. This cadmium-rich sludge can pollute surface waters as well as soils.

Cadmium strongly adsorbs to organic matter in soils. When cadmium is present in soils it can be extremely dangerous, as the uptake through food will increase. Soils that are acidified enhance the cadmium uptake by plants. This is a potential danger to the animals that are dependent upon the plants for survival. Cadmium can accumulate in their bodies, especially when they eat multiple plants. Cows may have large amounts of cadmium in their kidneys due to this. Earthworms and other essential soil organisms are